

Solutions



molarity, molality, mass percent, solubility effects, Raoult's Law, colligative properties

Solutions & Their Compositions

- Here we'll look at types of solutions and all their units

Types of Solutions

- A solution is a **homogeneous mixture**

TABLE 13.1 Examples of Solutions

State of Solution	State of Solvent	State of Solute	Example
Gas	Gas	Gas	Air
Liquid	Liquid	Gas	Oxygen in water
Liquid	Liquid	Liquid	Alcohol in water
Liquid	Liquid	Solid	Salt in water
Solid	Solid	Gas	Hydrogen in palladium
Solid	Solid	Liquid	Mercury in silver
Solid	Solid	Solid	Silver in gold

Composition

- ~~Mass Percent~~
- Molarity
- ~~Molality~~
- ~~Mole Fraction~~

Lucky You



Molarity

- Used **ALL** the time
- Tells us how much stuff per volume
- **M = moles of solute / liters of solution**
- Often seen symbolized in brackets,
e.g. **[Ag⁺]** means “*the concentration of the Ag⁺ ion*”

Molarity/Dilution Intermission

- **MV = mol**
- Mol in one solution will equal mol of stuff in “new” solution
- Therefore, *mols at beginning = mols when finished:*
 $\text{mol}_1 = \text{mol}_2$
- Therefore **$M_1V_1 = M_2V_2$**
- I will give you three to find one; such as, *What volume of Solution 1 (Molarity = blah) will I need to make 250 ml of Solution 2 with a molarity of blahblah?*

Mole Fraction

Used earlier for partial pressure

- Pretty obvious; the fraction of the total number of moles the substance in question is...
- **$X_s = \text{mols Solute} / \text{total mols}$**
- Use for finding how vapor pressure changes when you throw stuff into a solvent (later)

Density

- derp, but you may need it when converting molarity to molality
- **$D = m/V$**

QUESTION

How many milliliters of 18.4 M H_2SO_4 are needed to prepare 600.0 mL of 0.10 M H_2SO_4 ?

- 1) 1.8 mL
- 2) 2.7 mL
- 3) 3.3 mL
- 4) 4.0 mL
- 5) 4.6 mL

QUESTION

If 2.00 g of helium gas and 4.00 g of oxygen gas are mixed together what is the mole fraction of helium in the solution?

- 1) 0.500
- 2) 0.333
- 3) 0.800
- 4) 0.200
- 5) 0.666



QUESTION

The influence of temperature and temperature changes on many chemical processes and observations is quite significant. However, of the four common ways of expressing solution only one is influenced by temperature. Which of the following expressions is that?

- 1. Mass percent*
- 2. Molality*
- 3. Molarity*
- 4. Mole fraction*

ANSWER



Choice 3 is the only one of the four to be affected by temperature changes. This is because molarity depends on solution volume. Volume may vary with temperature. The other three expressions are mass based.

Section 11.1: Solution Composition

QUESTION



A solution of ammonia (NH_3 molar mass = 17.0 g/mol) that you would likely encounter in a general chemistry lab would have a molarity of approximately 15. If the mole fraction of NH_3 in the solution was 0.29, what would you determine as the density of the solution?

1. 0.26 g/mL

2. 0.92 g/mL

3. 0.39 g/mL

4. I don't see how to connect the mole fraction to the molarity and density.

Heat of Solution

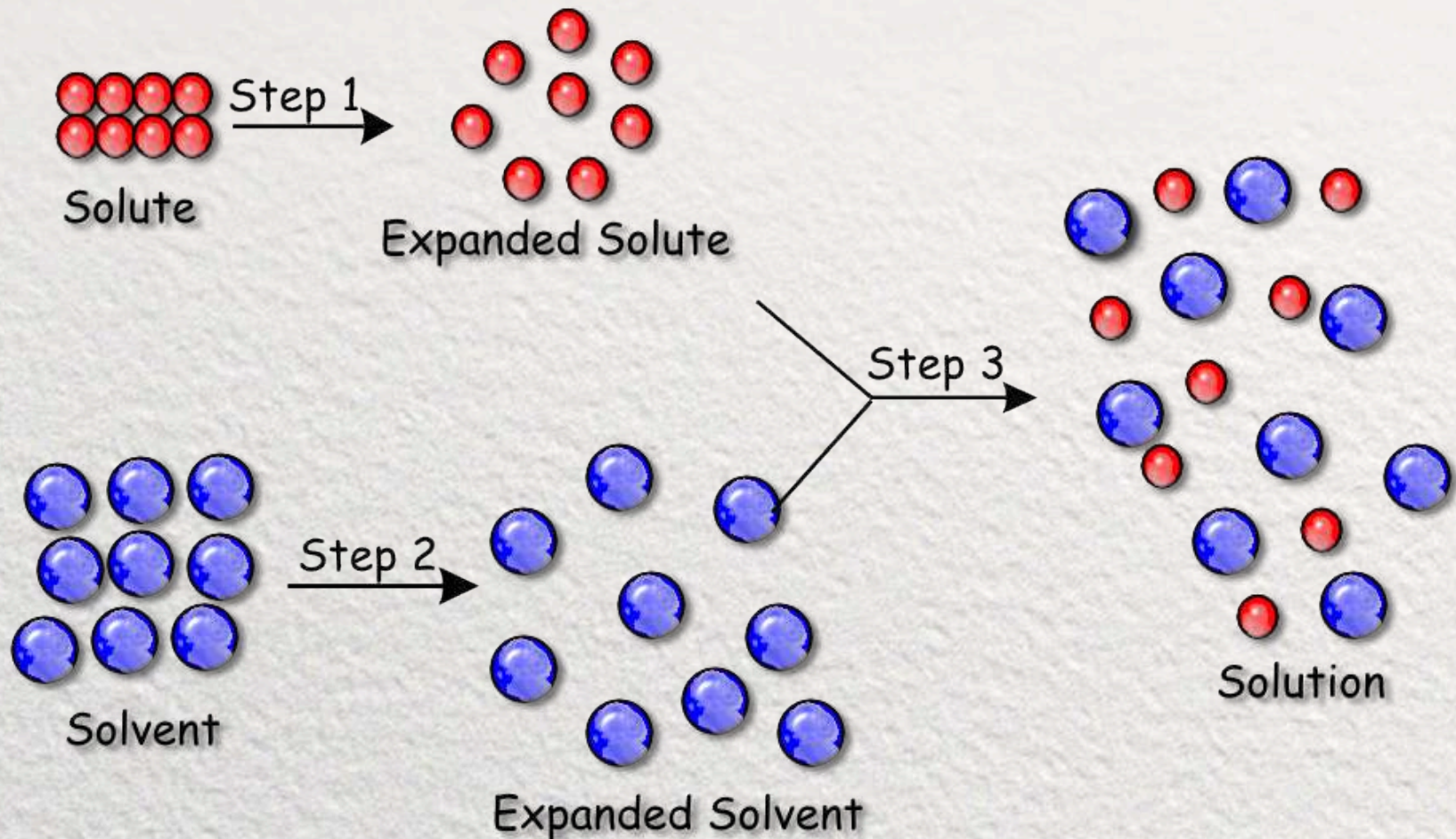
The **Heat of Solution** is the amount of heat energy absorbed (endothermic) or released (exothermic) when a specific amount of solute dissolves in a solvent.

Substance	Heat of Solution (kJ/mol)
NaOH	-44.51
NH₄NO₃	+25.69
KNO₃	+34.89
HCl	-74.84

Steps in Solution Formation

ΔH_1 Step 1 - Expanding the solute

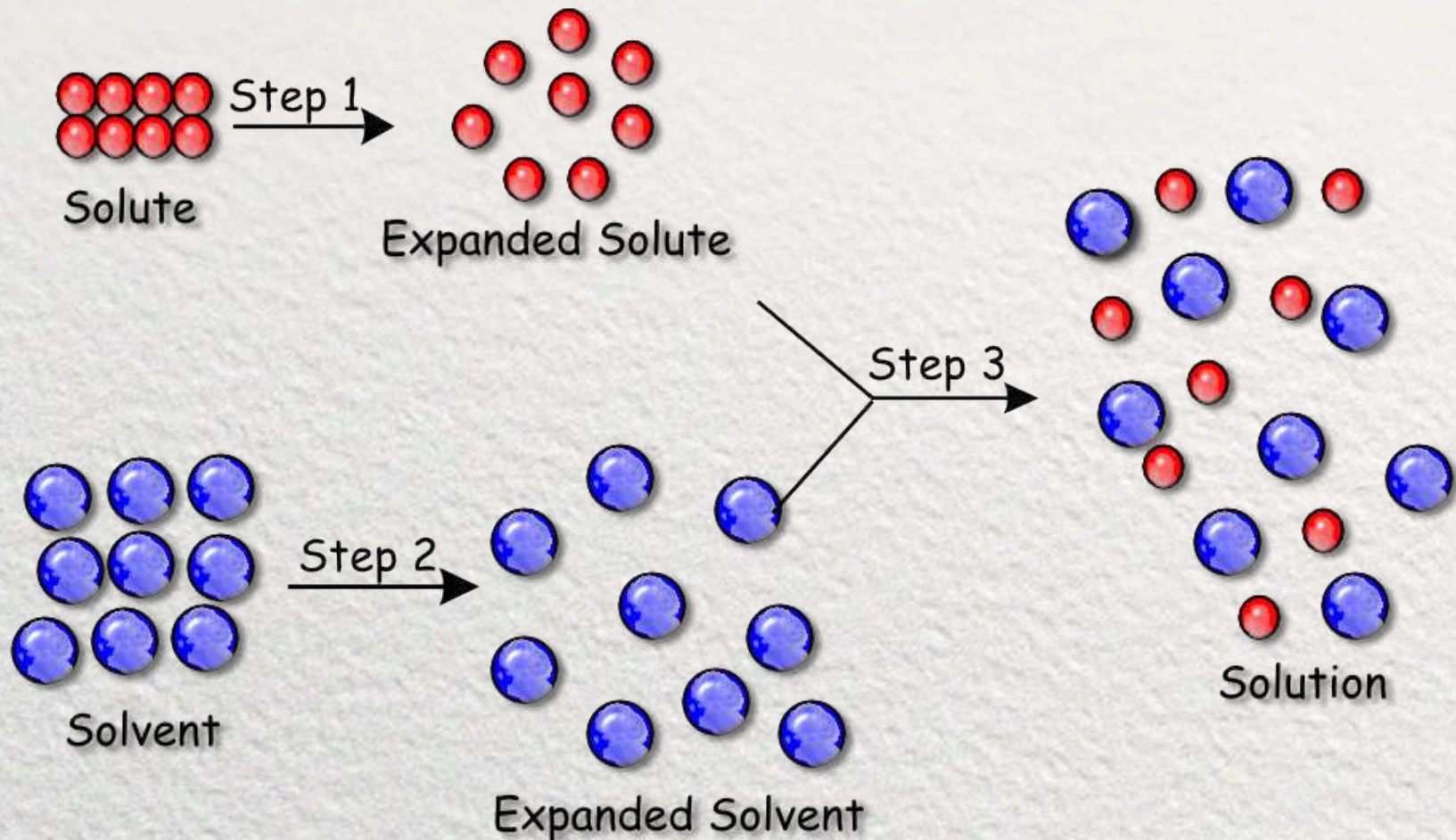
Separating the solute into individual components



Steps in Solution Formation

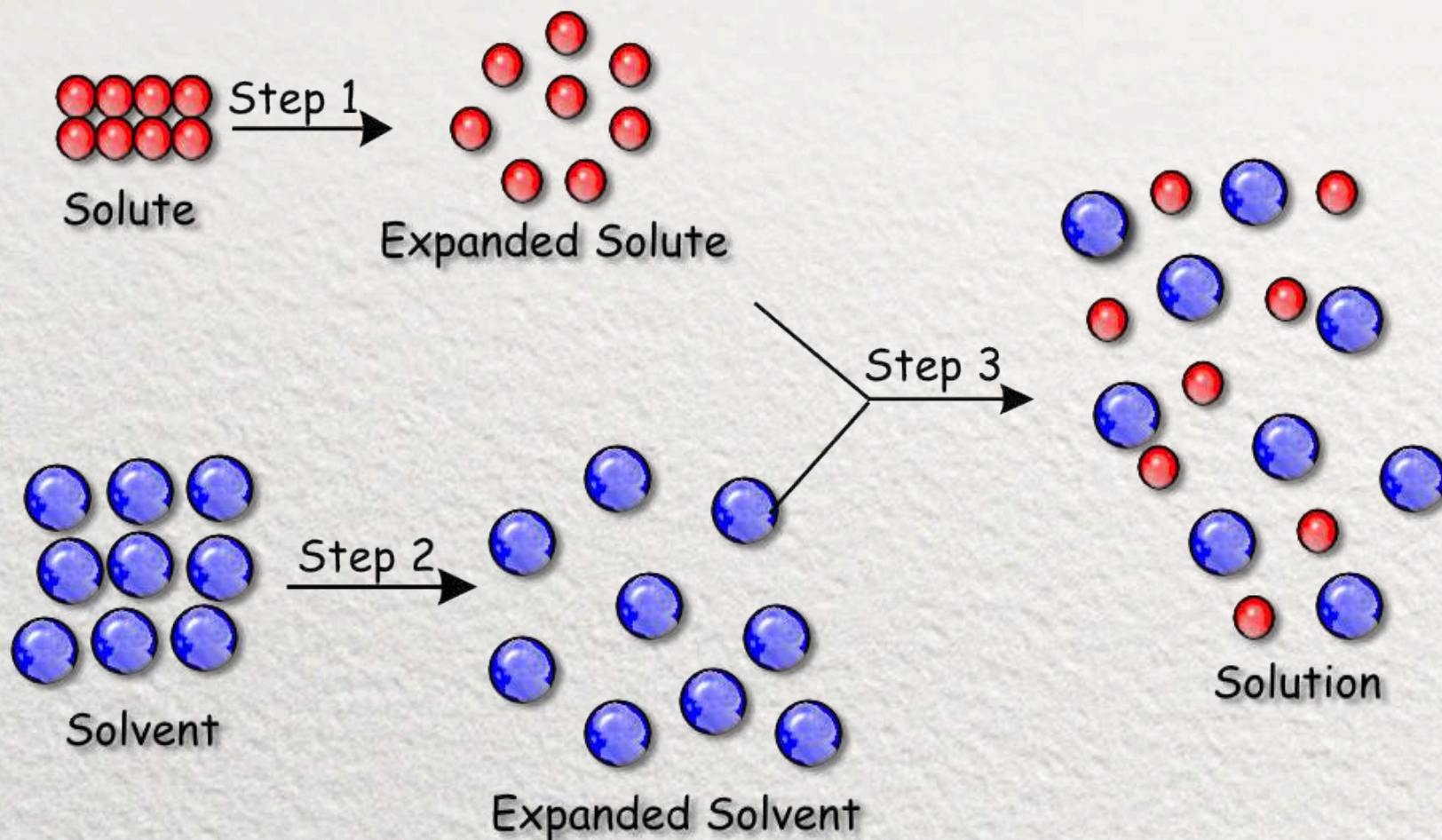
ΔH_2 Step 2 - Expanding the solvent

Overcoming intermolecular forces of the solvent molecules



Steps in Solution Formation

ΔH_3 Step 3 - Interaction of solute and solvent to form the solution



Predicting Solution Formation

Solvent/ Solute	ΔH_1	ΔH_2	ΔH_3	$\Delta H_{\text{sol'n}}$	Outcome
Polar/ Polar	+ large	+ large	- large	+/- small	Solution forms
Polar/ Nonpolar	+ small	+ large	+/- small	+ large	No solution forms
Nonpolar/ Nonpolar	+ small	+ small	+/- small	+/- small	Solution forms
Nonpolar/ polar	+ large	+ small	+/- small	+ large	No solution forms

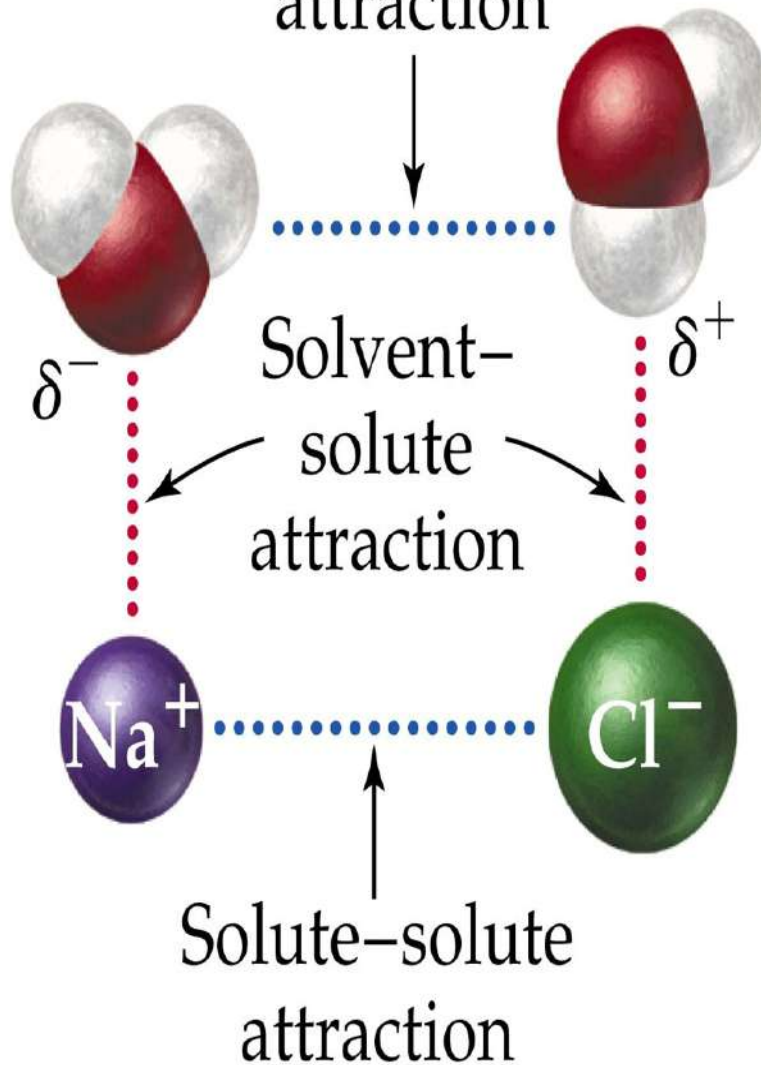
Factors Affecting Solubility

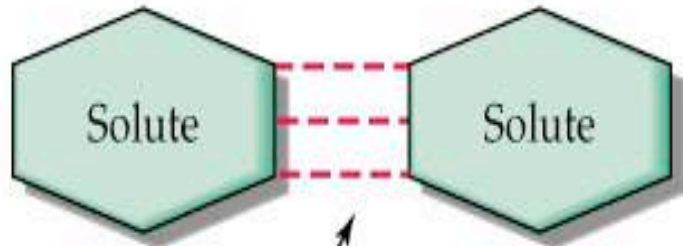
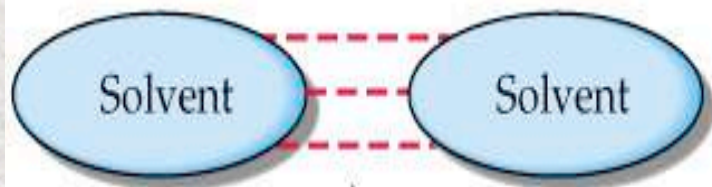
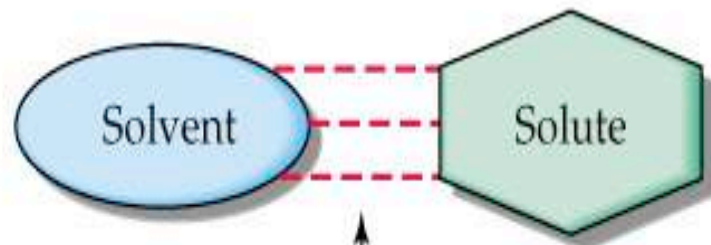


Structural Effects

- ***Like Dissolves Like***
- Polar solvents have a tendency to dissolve polar solutes, same with nonpolar/nonpolar
- e.g. fat-soluble vitamins (nonpolar) can dissolve and stay in your fat, not go out with the pee pee

Solvent-solvent
attraction

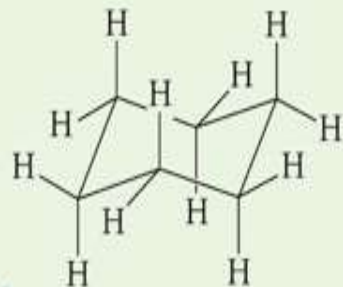




Solutions form when these three kinds of forces are similar.

HYDROGEN BONDING AND AQUEOUS SOLUBILITY

The presence of OH groups capable of hydrogen bonding with water enhances the aqueous solubility of organic molecules.

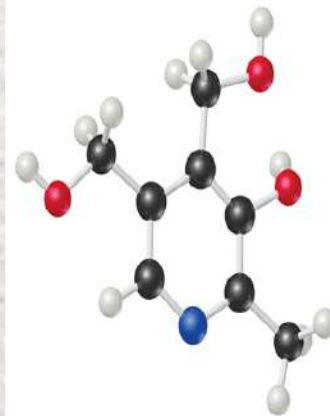


Cyclohexane, C_6H_{12} , which has no polar OH groups, is essentially insoluble in water.

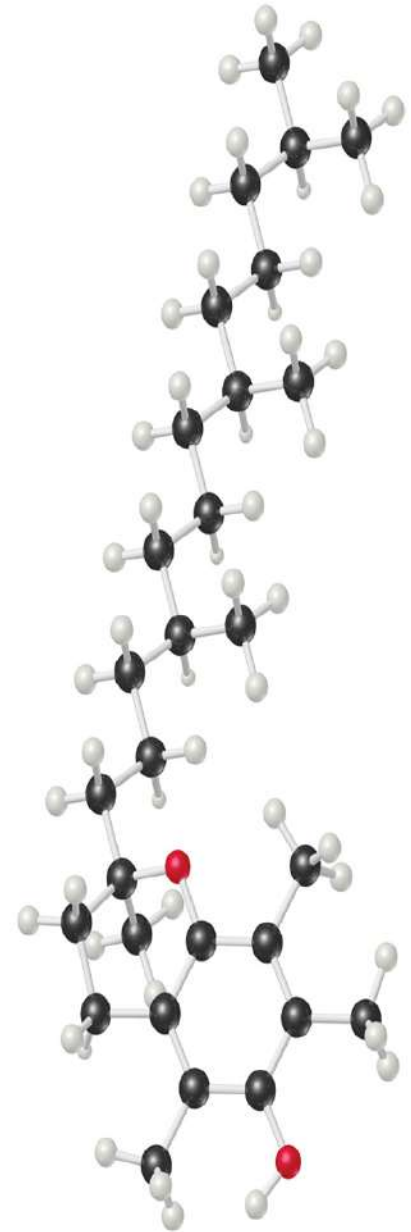


Glucose, $C_6H_{12}O_6$, has five OH groups is highly soluble in water.

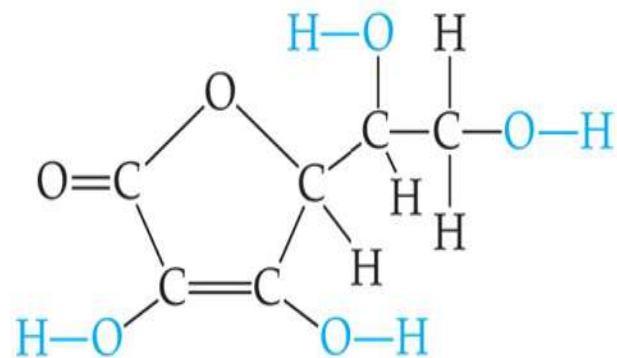
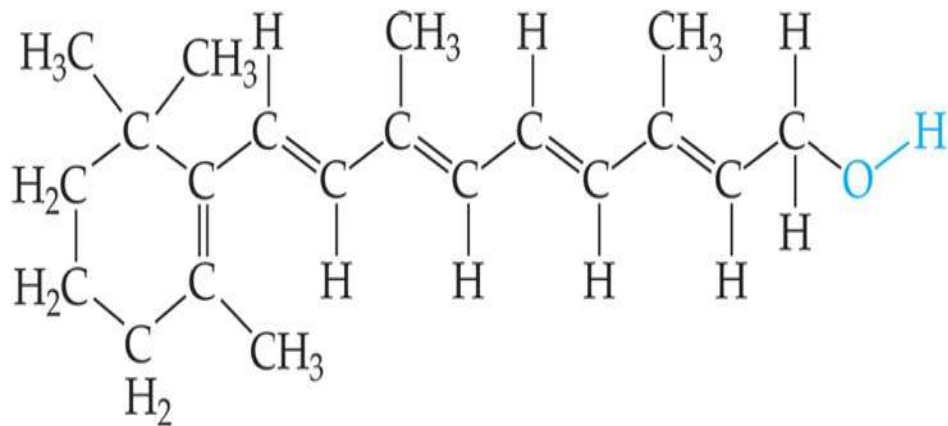
Which is more water soluble?



Vitamin B₆



Vitamin E



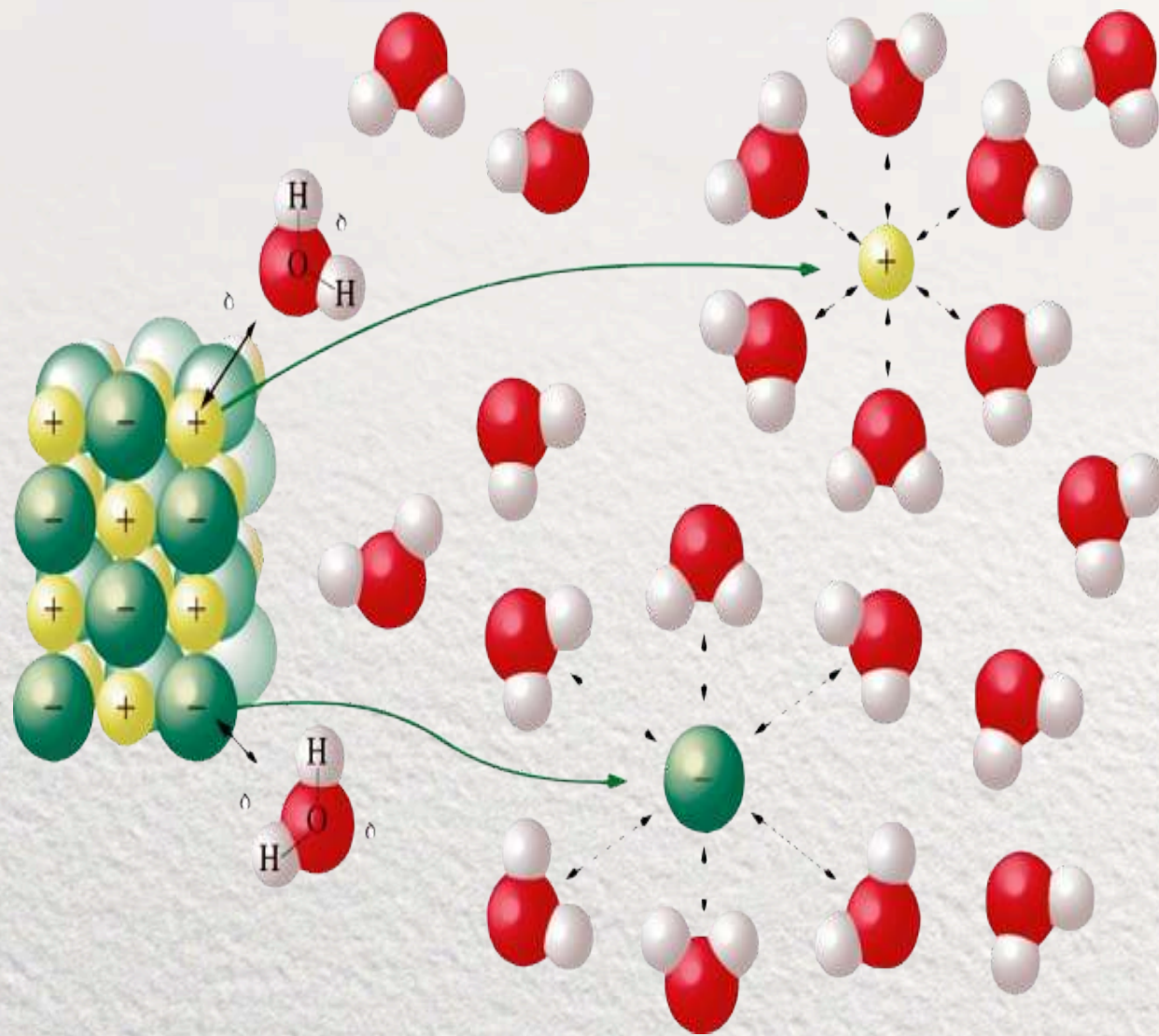
Vitamin A



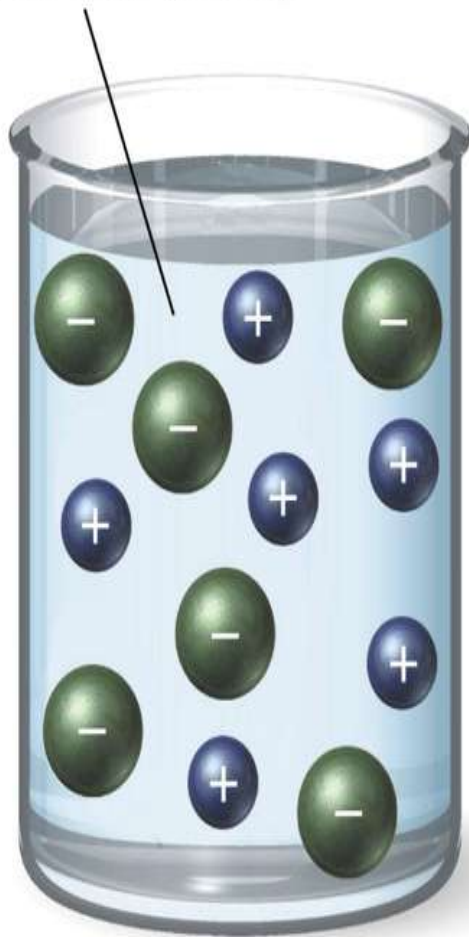
Vitamin C

Which is more water soluble?

- When Ionic compounds get broken up = **Dissociation**
- Called **Electrolytes**

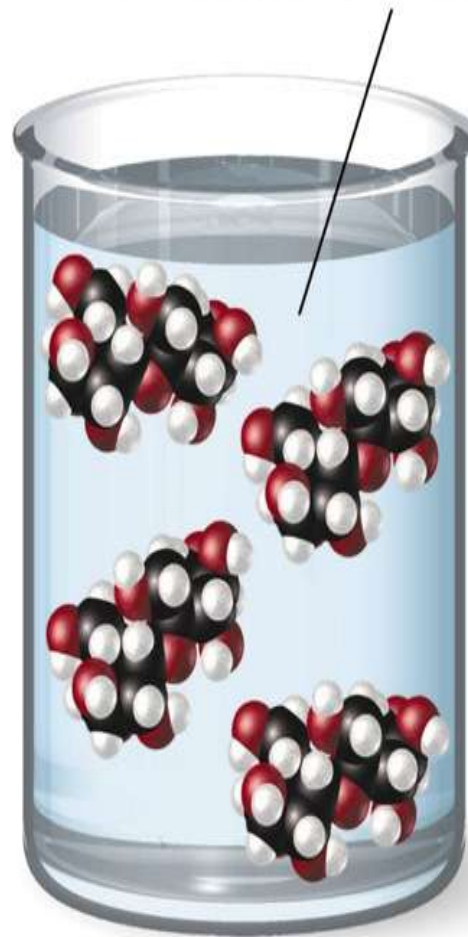


Dissolved ions (NaCl)



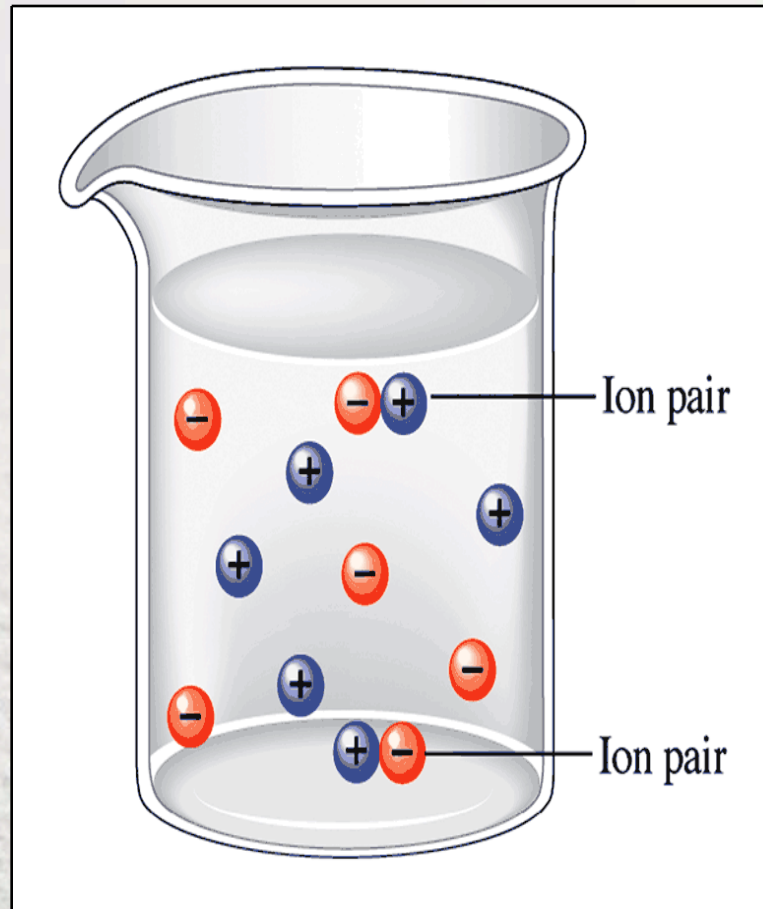
Electrolyte solution

Dissolved molecules (sugar)



Nonelectrolyte solution

- **Van't Hoff factor (i)** tells us how many particles we can get from a dissociation (plays a big role *later*)
- e.g. sugar does not dissociate, $\therefore i = 1$
for NaCl, $i = 2$
for CaCl₂, $i = 3$
- not always so ideal...



e.g. in an aqueous solution a few ions aggregate,
forming ion pairs that behave as a unit.

TABLE 11.6 Expected and Observed Values of the van't Hoff Factor for 0.05 *m* Solutions of Several Electrolytes

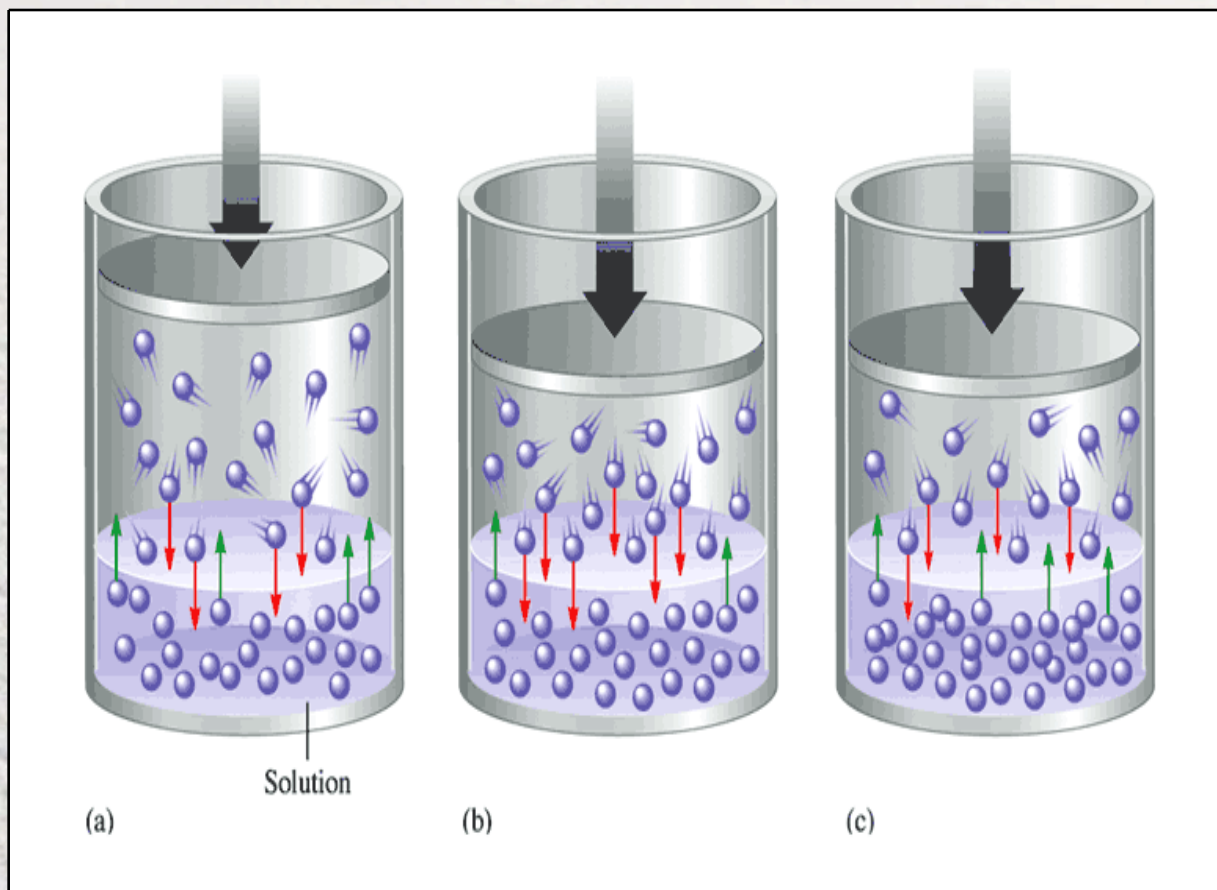
<u>Electrolyte</u>	<u><i>i</i> (expected)</u>	<u><i>i</i> (observed)</u>
NaCl	2.0	1.9
MgCl ₂	3.0	2.7
MgSO ₄	2.0	1.3
FeCl ₃	4.0	3.4
HCl	2.0	1.9
Glucose*	1.0	1.0

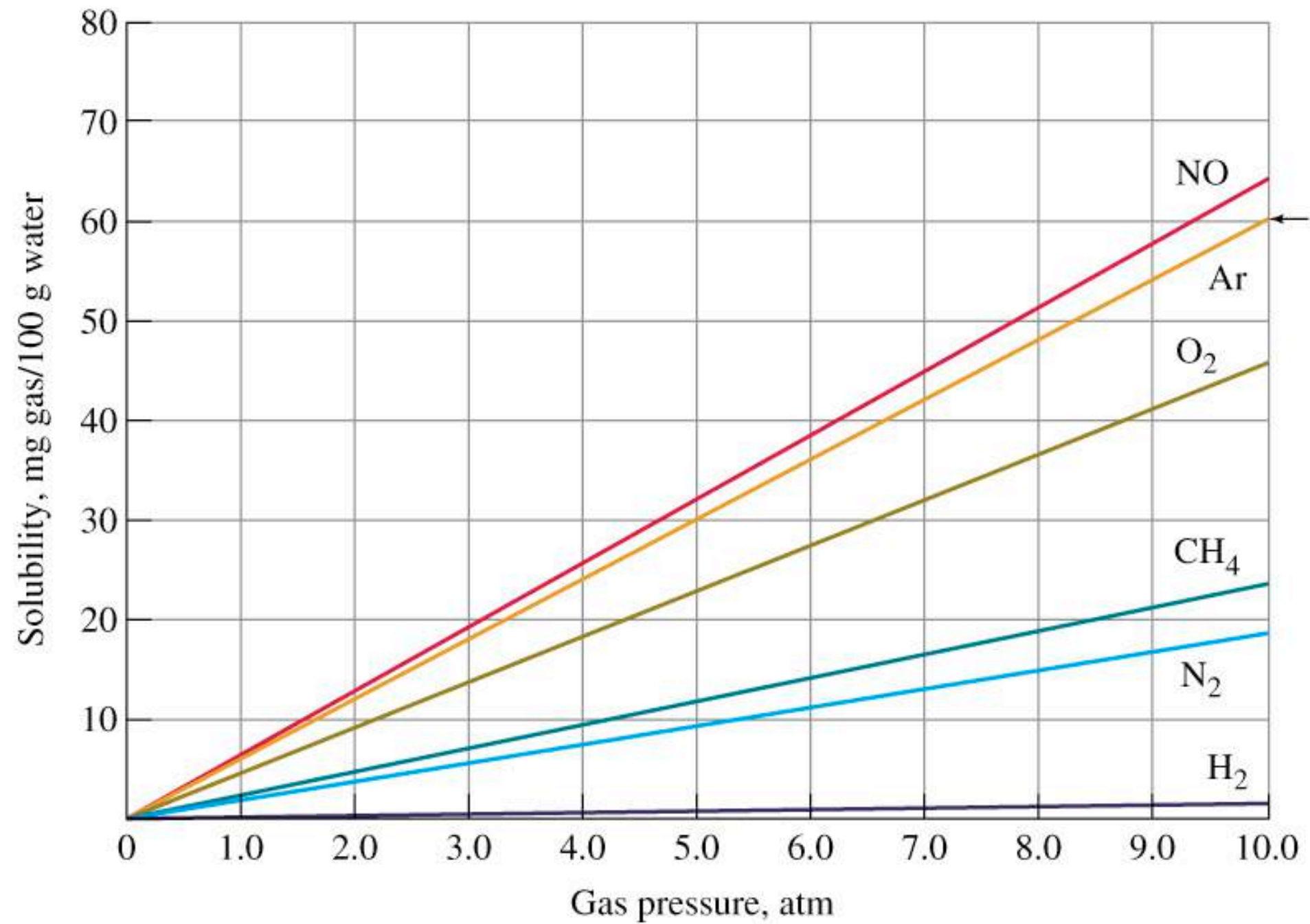
*A nonelectrolyte shown for comparison.

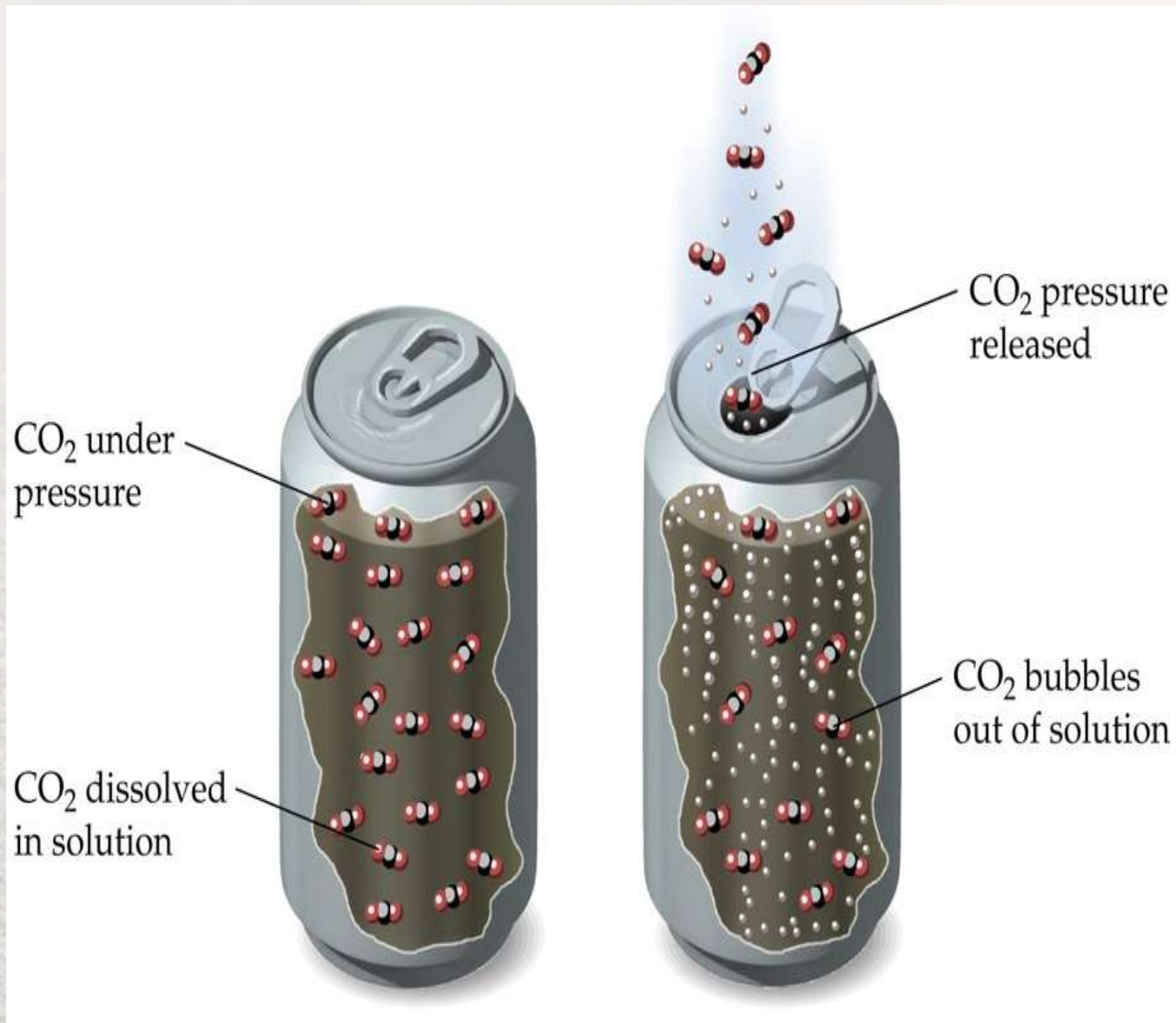
Pressure Effects

- Almost no effect when dissolving solids into liquids,
- **but** BIG role when gases are dissolved
- **Henry's Law** basically says that you can press more gas into a solution $C = kP$
Concentration(M) = constant · Partial Pressure
- *The amt of gas dissolved in a liquid is directly proportional to the pressure of the gas above the soln*

Figure 11.5: (a) A gaseous solute in equilibrium with a solution. (b) The piston is pushed in, increasing the pressure of the gas and number of gas molecules per unit volume. This causes an increase in the rate at which the gas enters the solution, so the concentration of dissolved gas increases. (c) The greater gas concentration in the solution causes an increase in the rate of escape. A new equilibrium is reached.









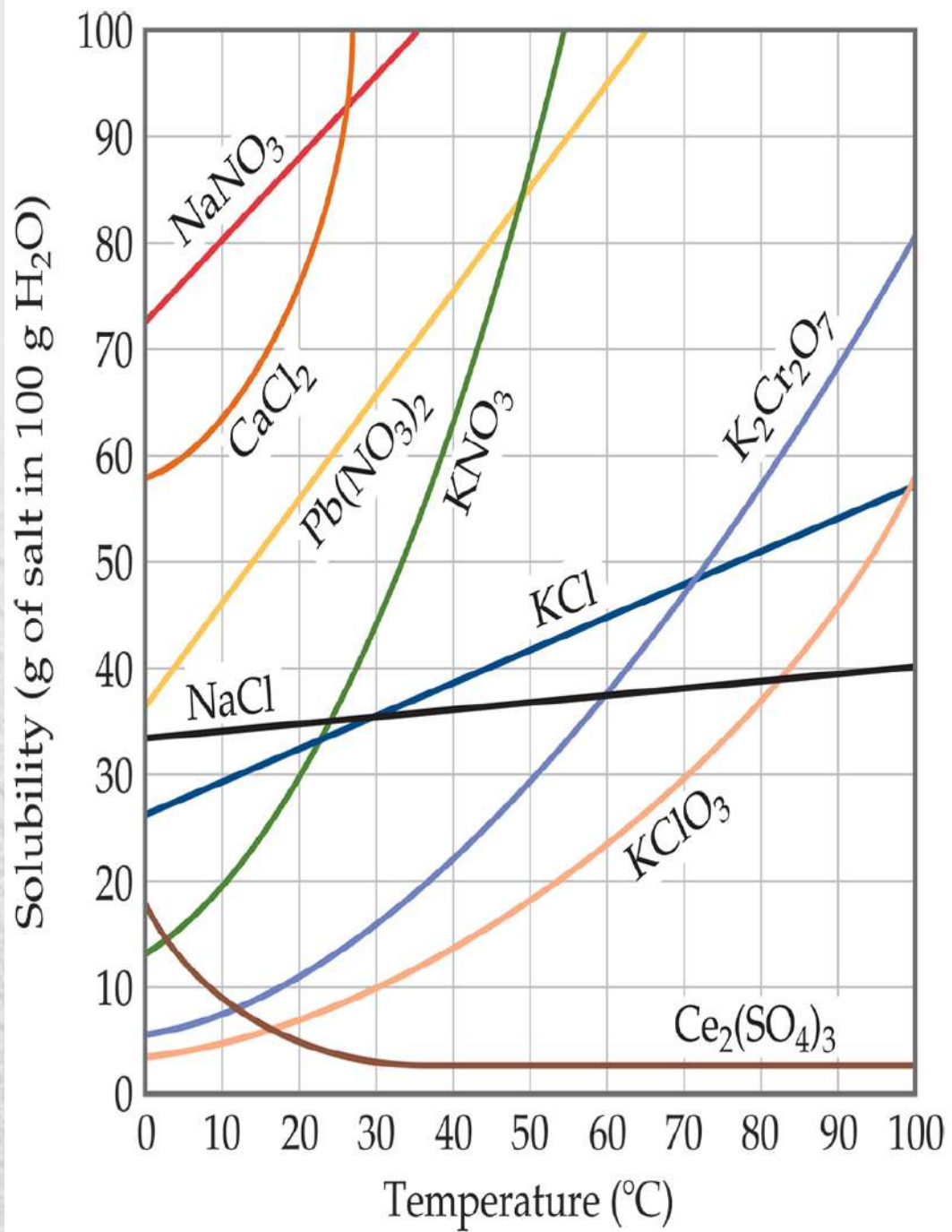
TV
PG

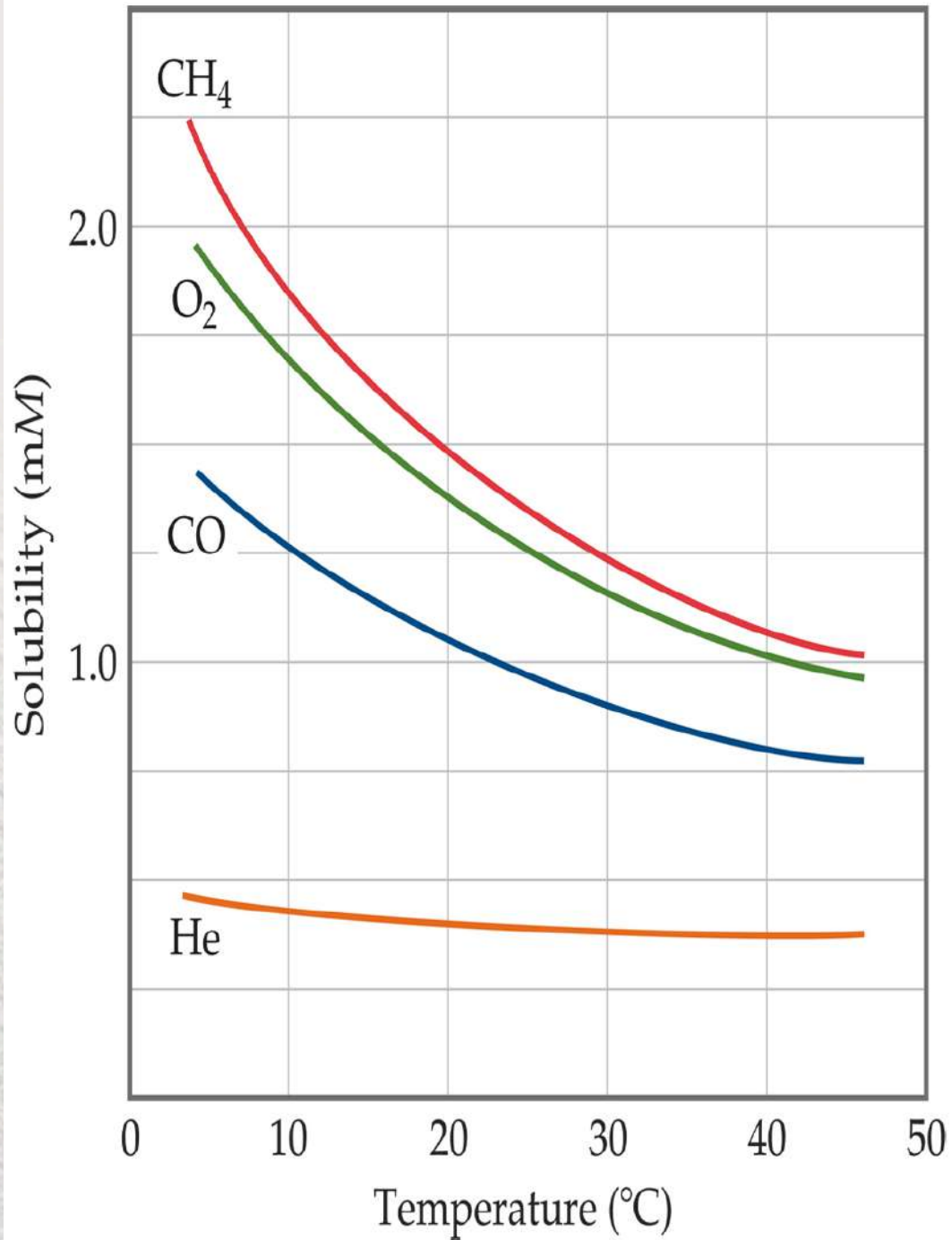


Discovery
CHANNEL
HD

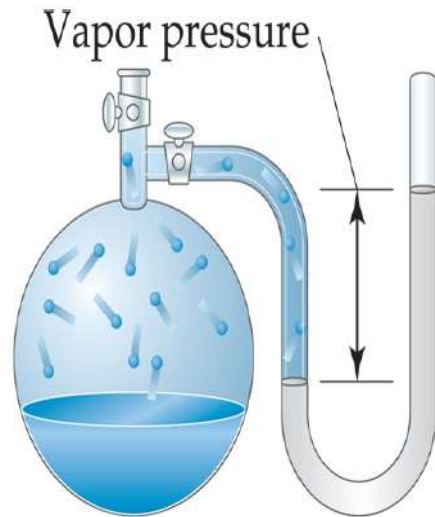
Temperature Effects

- For solids in liquids, the solubility almost always increases with temp
- Solubility of gases is practically reverse of what it is for solid/liquid solutions
- To wit, *the higher the temp, the **LESS** soluble a gas*, in general

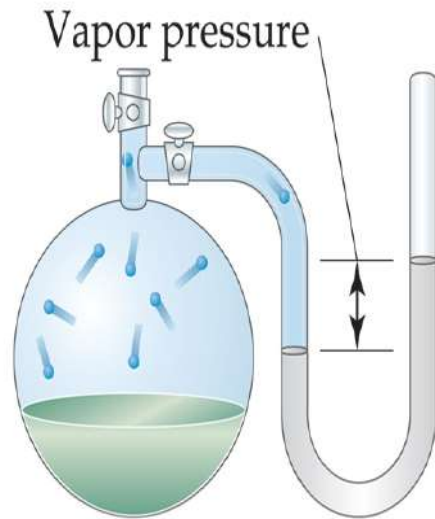




The Vapor Pressures of Solutions



Solvent alone



Solvent + solute

- *A nonvolatile solute lowers the vapor pressure of the solvent.*
- the nonvolatile solute decreases the escaping tendency of the solvent molecules
- this plays a huge role in soln properties

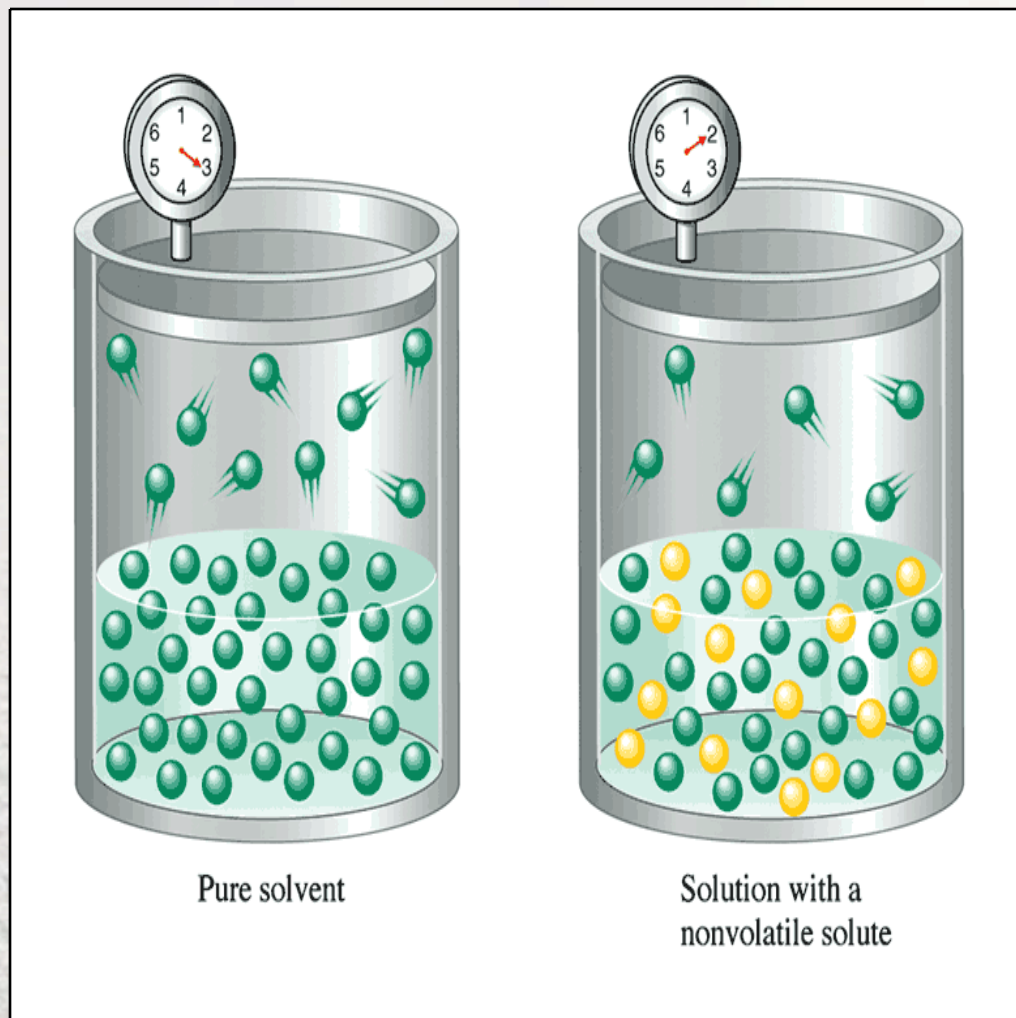


Figure 11.10: The presence of a nonvolatile solute inhibits the escape of solvent molecules from the liquid and so lowers the vapor pressure of the solvent.

Vapor Pressure Lowering

- aka **Raoult's Law**
- basically, adding a nonvolatile solute **lowers the vp**
- so how MUCH does the vapor pressure lower?
- first time we use the mole fraction (**X**)...

- 
- $P_X = v$
 - $P_X^\circ = \text{vapor solvent}$
 - $\mathbf{X} = \text{the}$

QUESTION

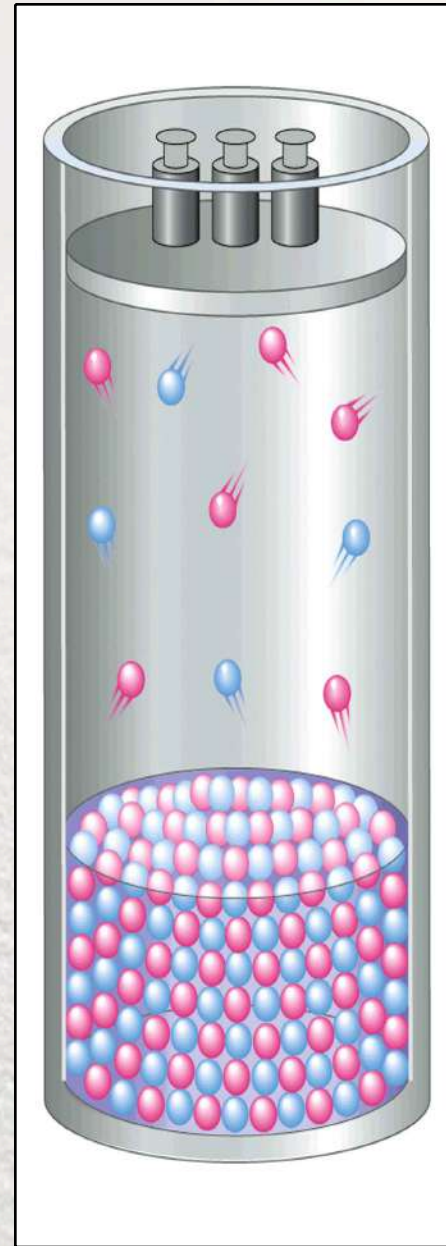
A salt solution sits in an open beaker. Assuming constant temperature and pressure, the vapor pressure of the solution:

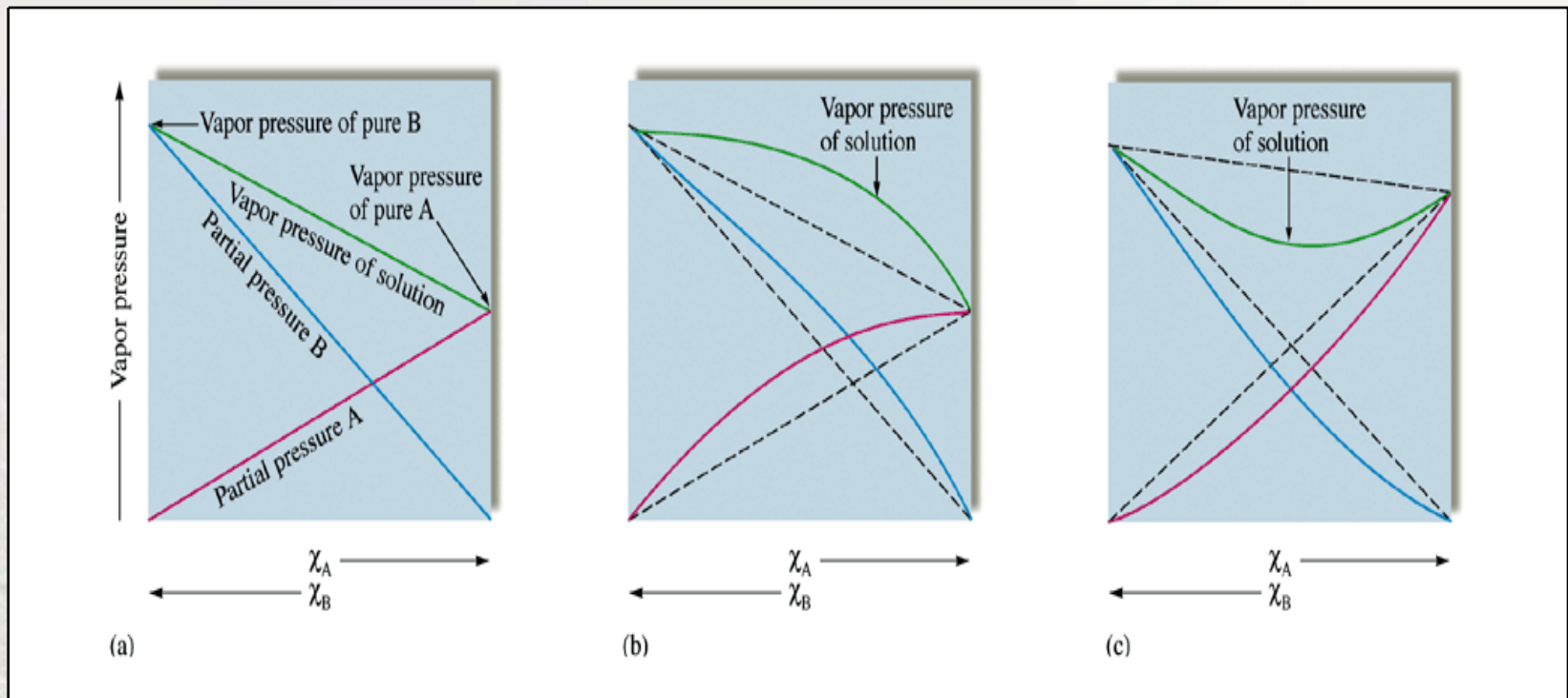
- 1) increases over time.
- 2) decreases over time.
- 3) stays the same over time.
- 4) Need to know which salt is in the solution to answer this.
- 5) Need to know the temperature and pressure to answer this.

Raoult's Law and Two Liquids

- The total vapor pressure of a mixture of two liquids should be the sum of the partial pressures of each liquid.
- $P_{\text{TOTAL}} = X_A P_A^\circ + X_B P_B^\circ$
- Fair warning: Raoult's Law only applies to ideal solutions.

When a solution contains two volatile components, both contribute to the total vapor pressure.

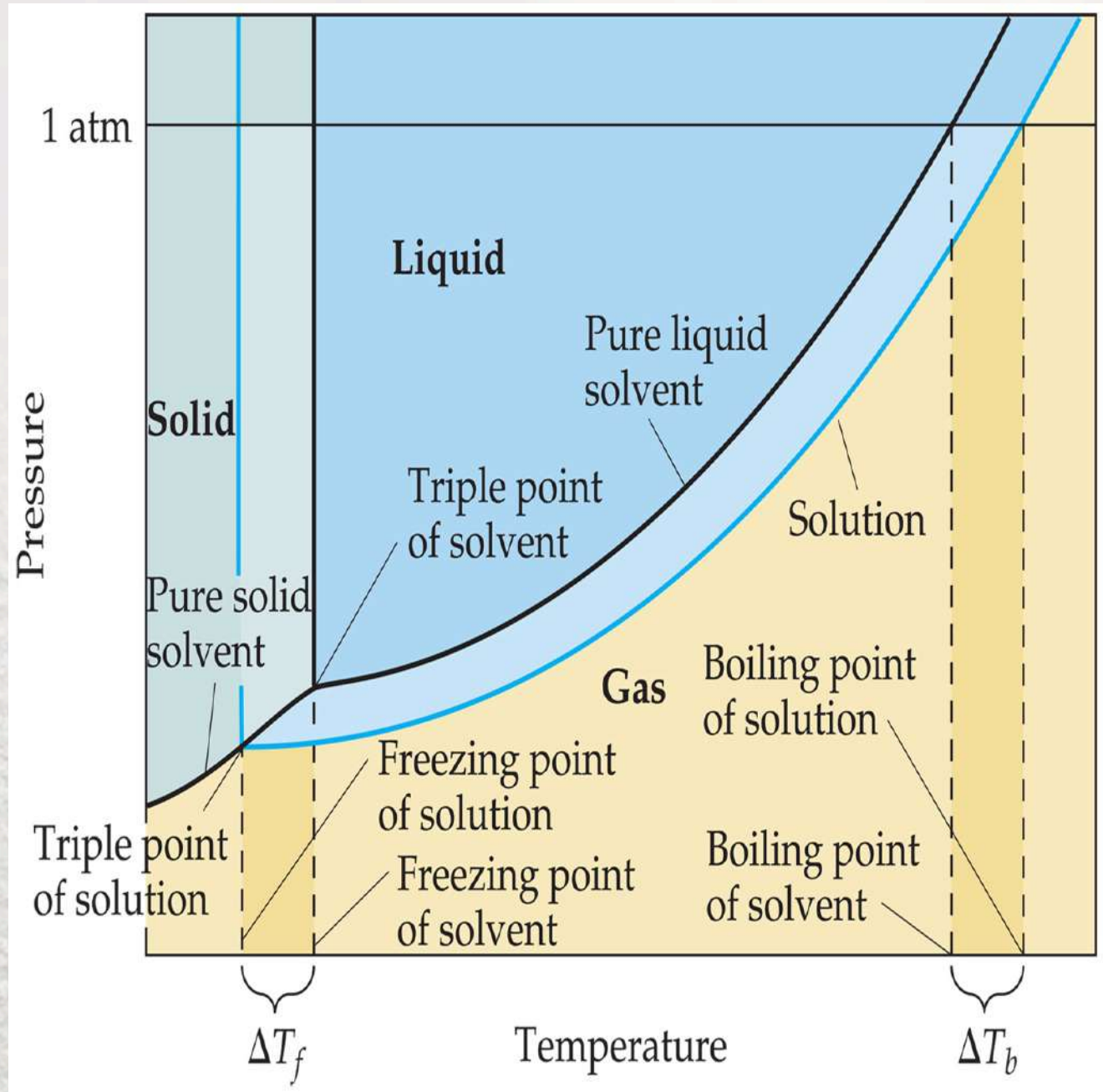




Vapor pressure for a solution of two volatile liquids. (a) The behavior predicted for an ideal liquid-liquid solution by Raoult's law. (b) A solution for which P_{TOTAL} is larger than the value calculated from Raoult's law. This solution shows a positive deviation from Raoult's law. (c) A solution for which P_{TOTAL} is smaller than the value calculated from Raoult's law. This solution shows a negative deviation from Raoult's law.

- Big Picture: Phase diagrams for pure water (black lines) and for an aqueous solution containing a nonvolatile solute (blue lines)

Do you see the effect it has on freezing point and boiling point?...



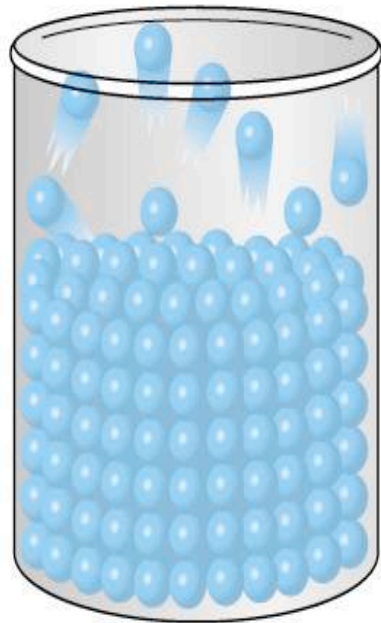
Collective Properties

- These are properties of **many** particles of **many** **type** are floating at
- Warning: M

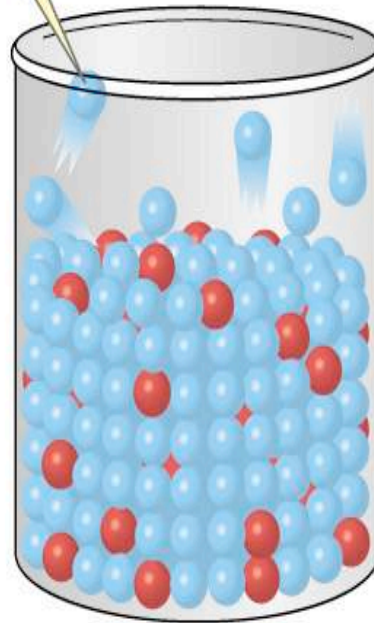
Boiling Point Elevation

- The addition of a solute interferes with a solvent's ability to make a vapor, so its vapor pressure lowers
- This makes it more difficult to boil
- This means you have to pile on the energy to get the vapor pressure to where it matches the atmospheric pressure
- This means the boiling point increases...

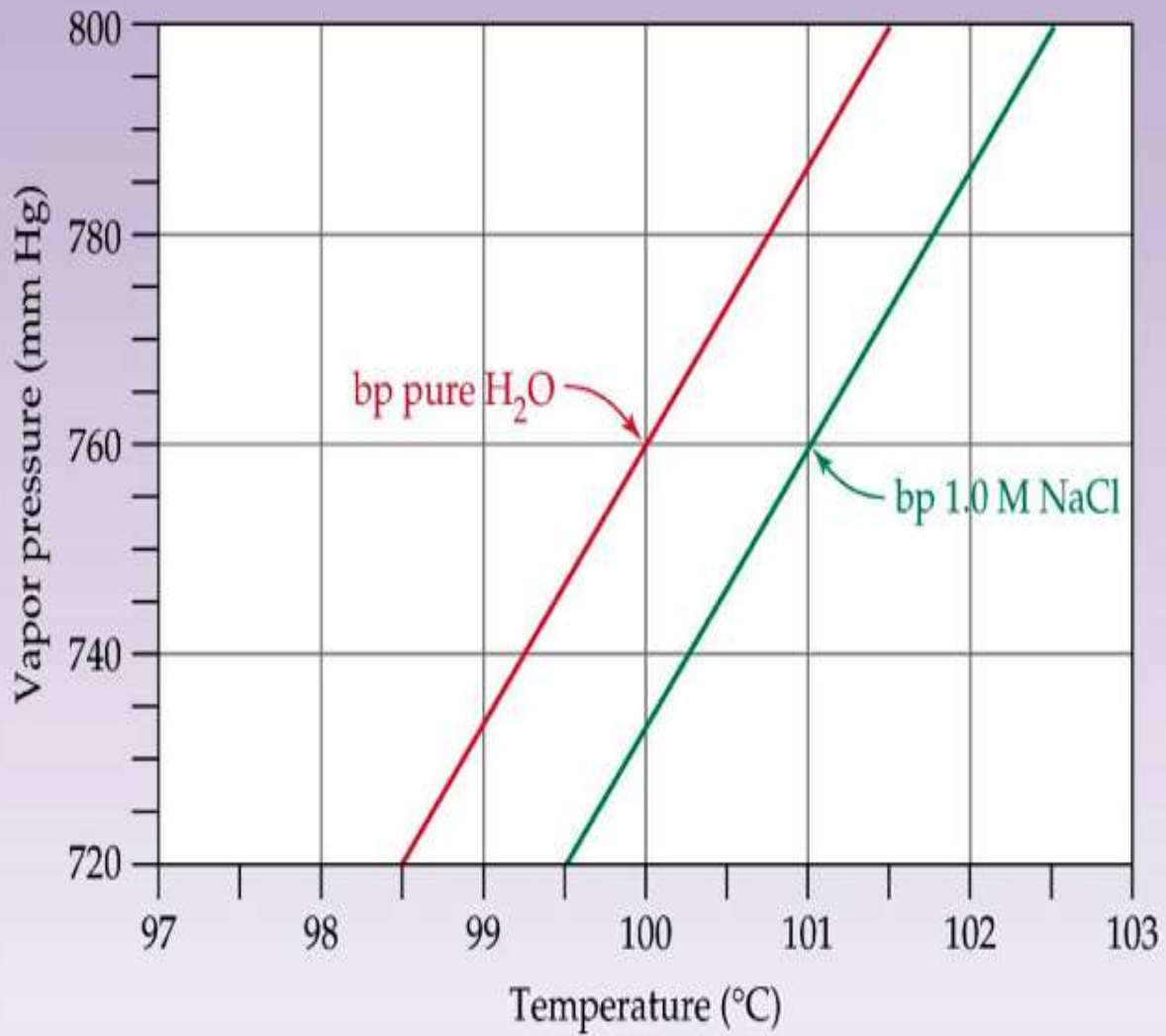
Fewer solvent molecules
leave surface, lowering
vapor pressure



● Pure solvent



● Solvent with
nonvolatile solute

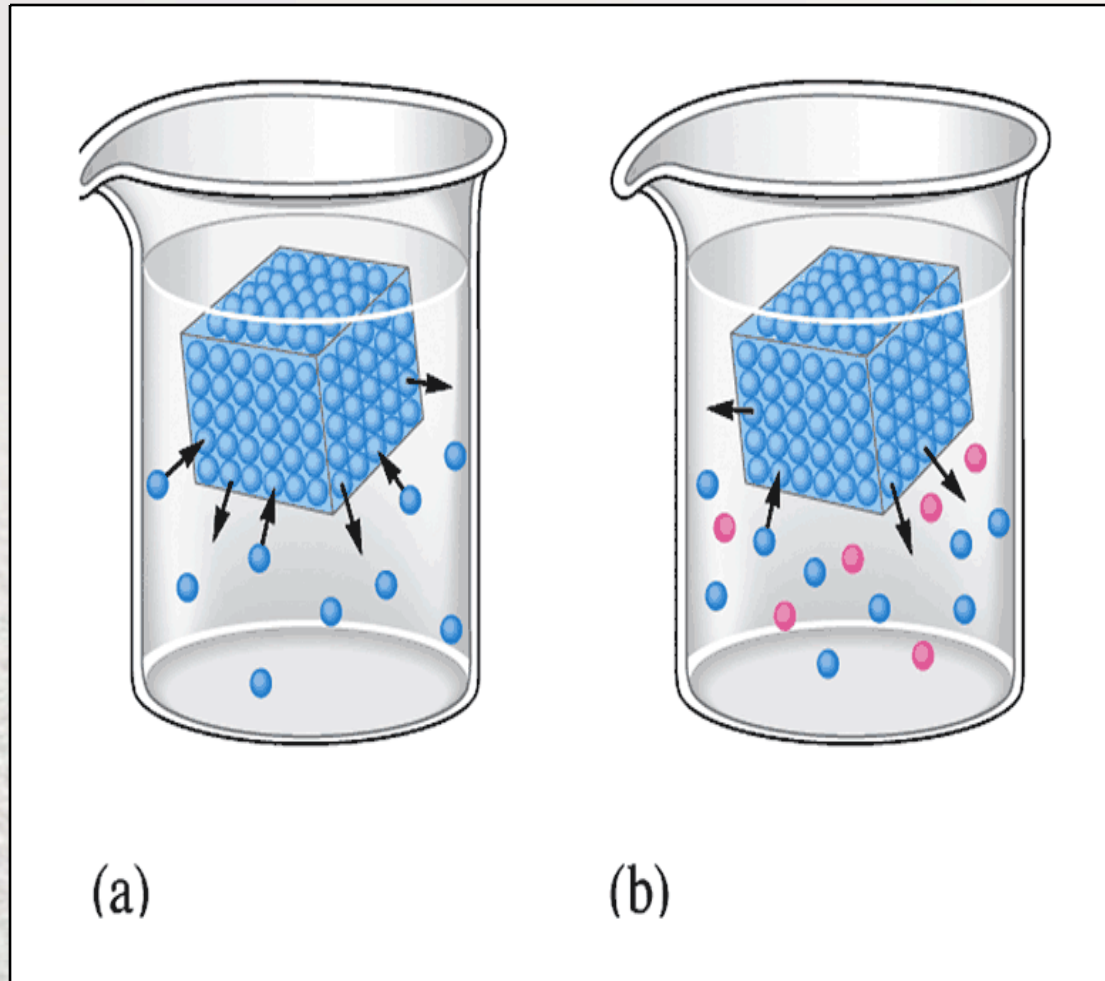


Boiling Point Elevation

- $\Delta T = i k_b m$
 - i = Van't Hoff factor
 - k_b = bp elevation constant
 - m = molality

Freezing Point Depression

- Solute also interferes with the ability of a solvent to freeze
- This lowers the freezing point



(a) Ice in equilibrium with liquid water. (b) Ice in equilibrium with liquid water containing a dissolved solute (shown in pink).

The addition of antifreeze lowers the freezing point of water in a car's radiator.



And is why salt
is dumped on
icy roads back
east

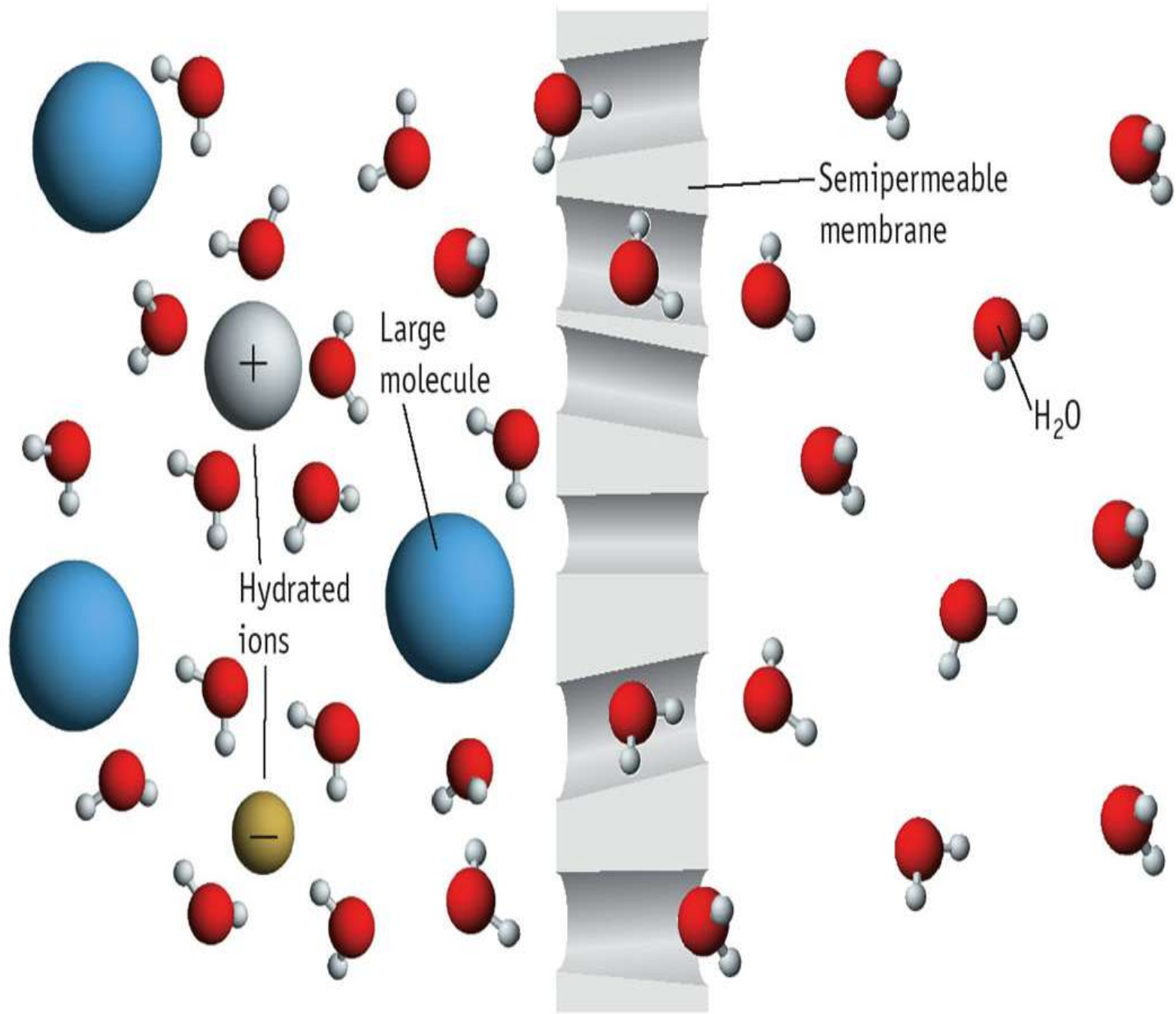


Freezing Point Depression

- $\Delta T = i k_f m$
 - i = Van't Hoff factor
 - k_f = fp depression constant
 - m = molality

Osmotic Pressure

- If a pure solvent and a solution are **separated** by a “semi-permeable” membrane, the solvent will flow through the membrane to try and dilute the solution

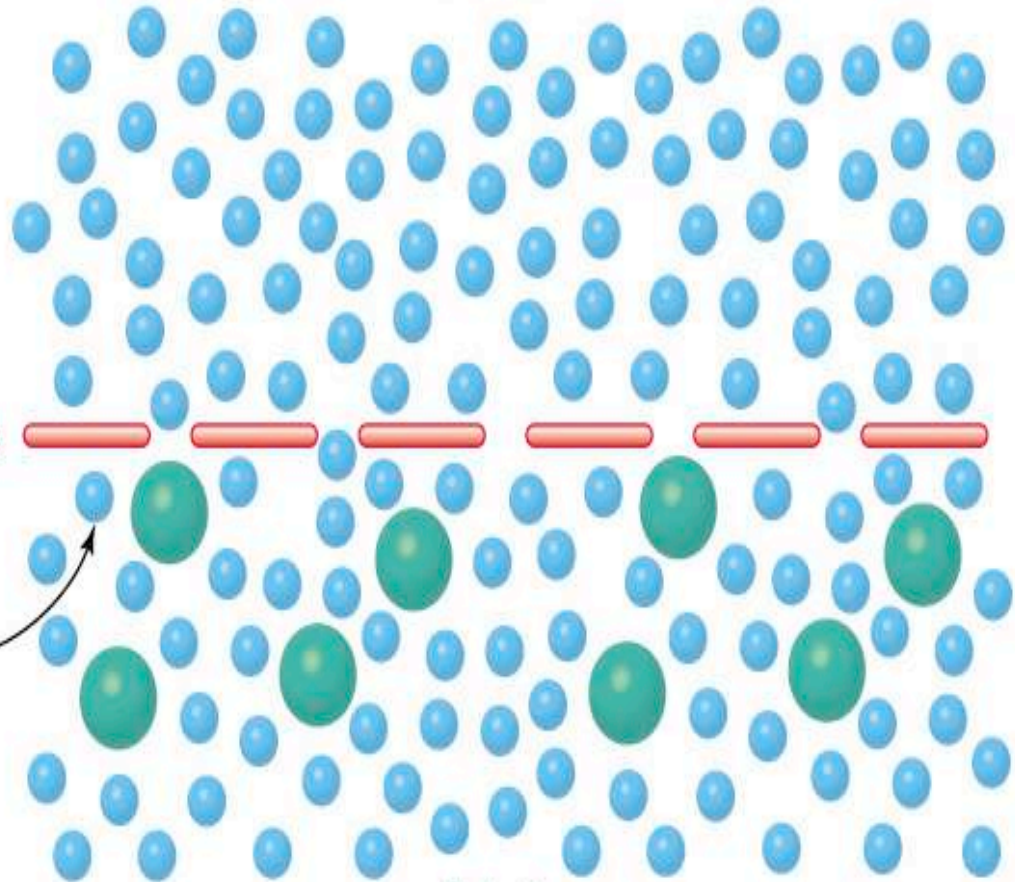


Pure solvent

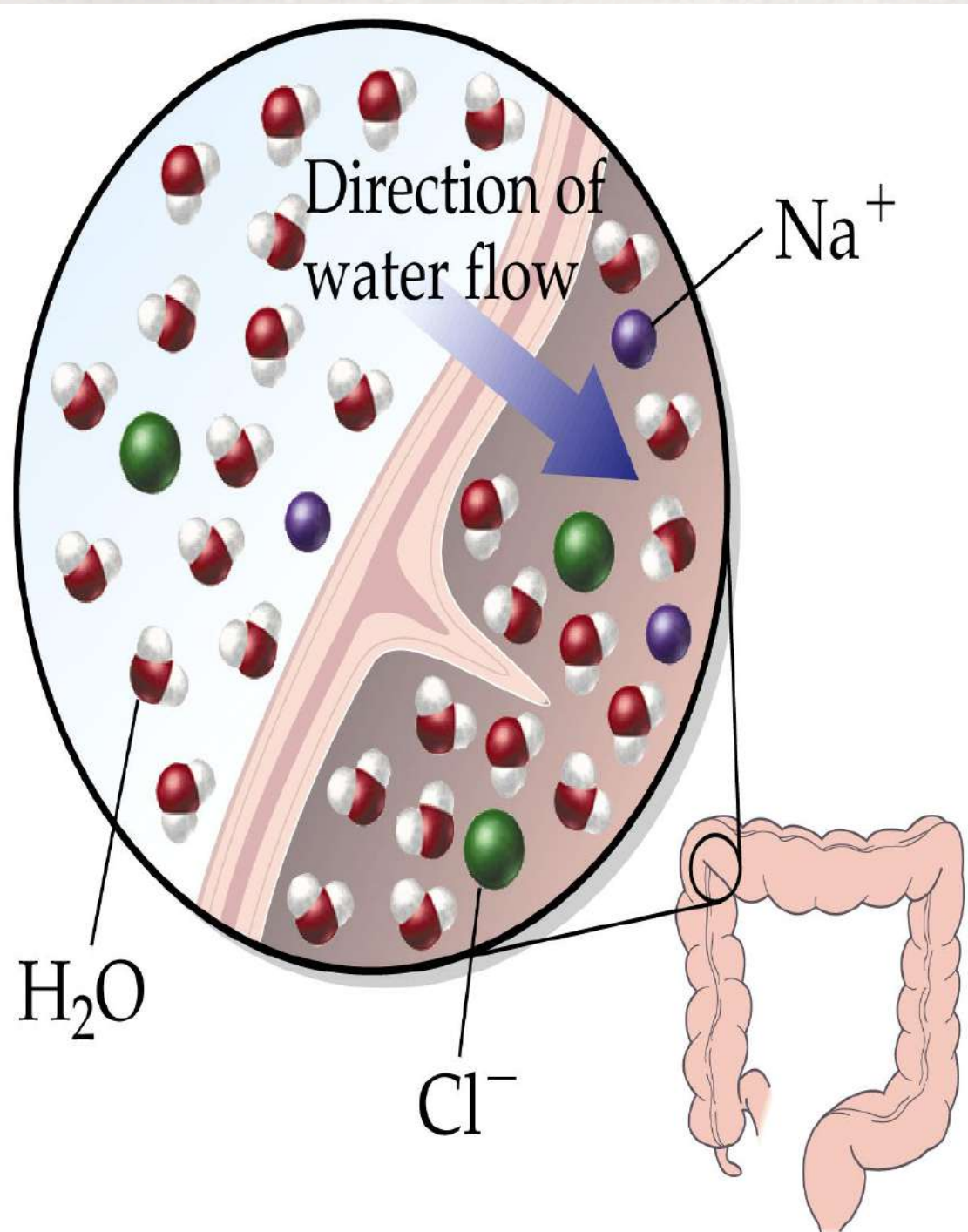
Membrane

Solvent molecules on the solution side have a lower concentration than molecules on the pure solvent side.

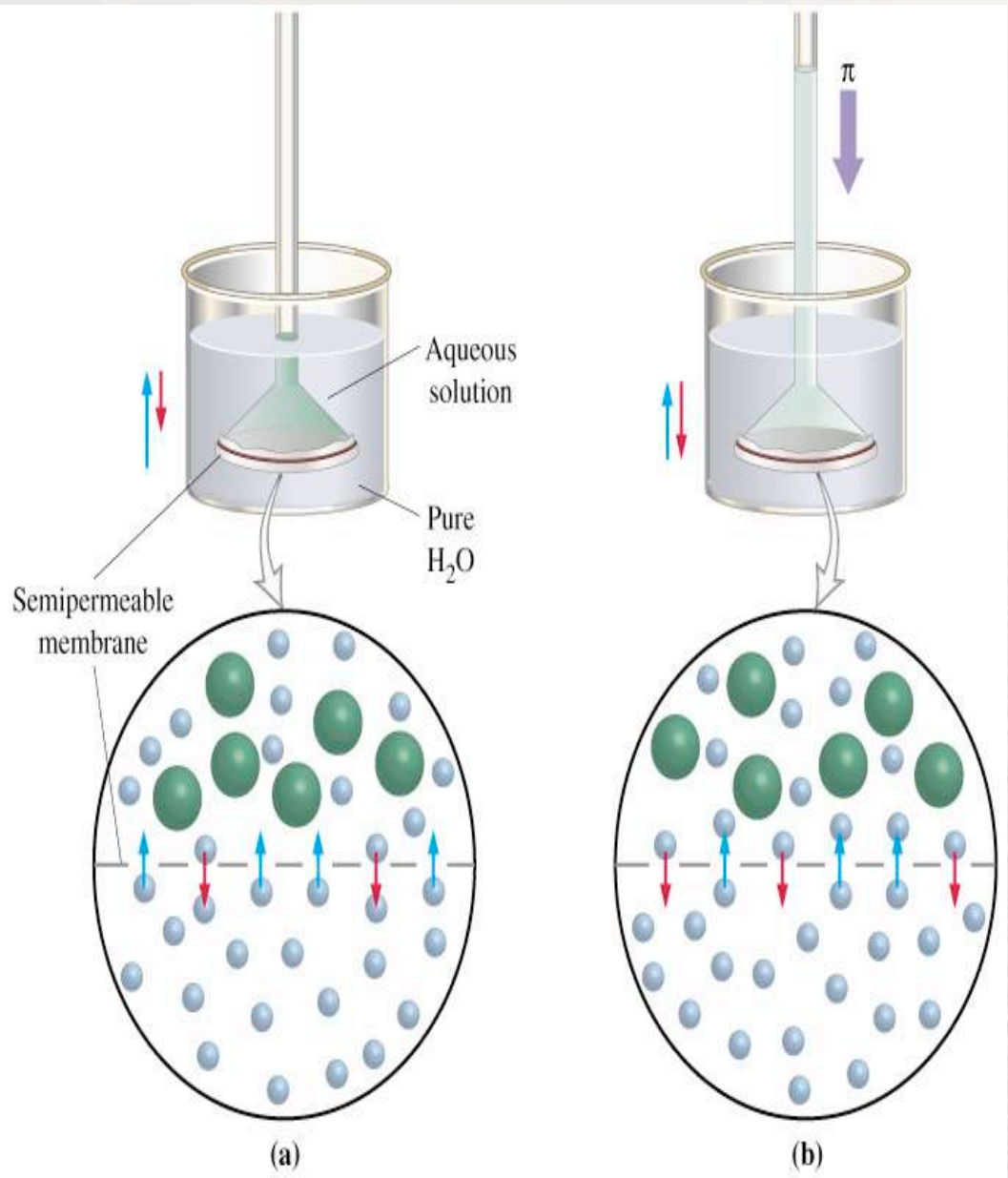
Solution

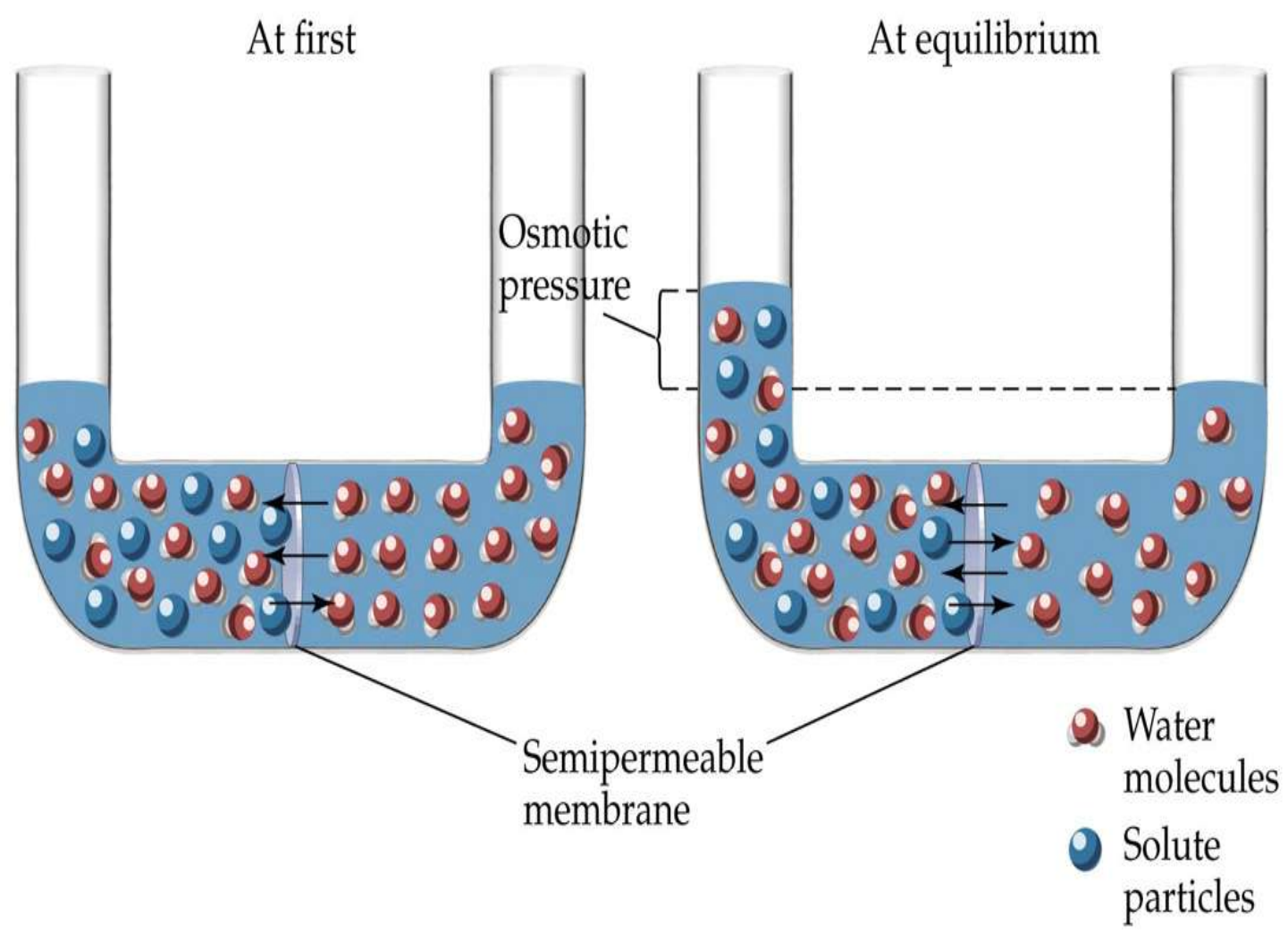


- Why drinking salt water will dehydrate you



- One must apply an “***osmotic pressure***” to stop this from happening
- The more concentrated the solution the more osmotic pressure it takes to stop it...





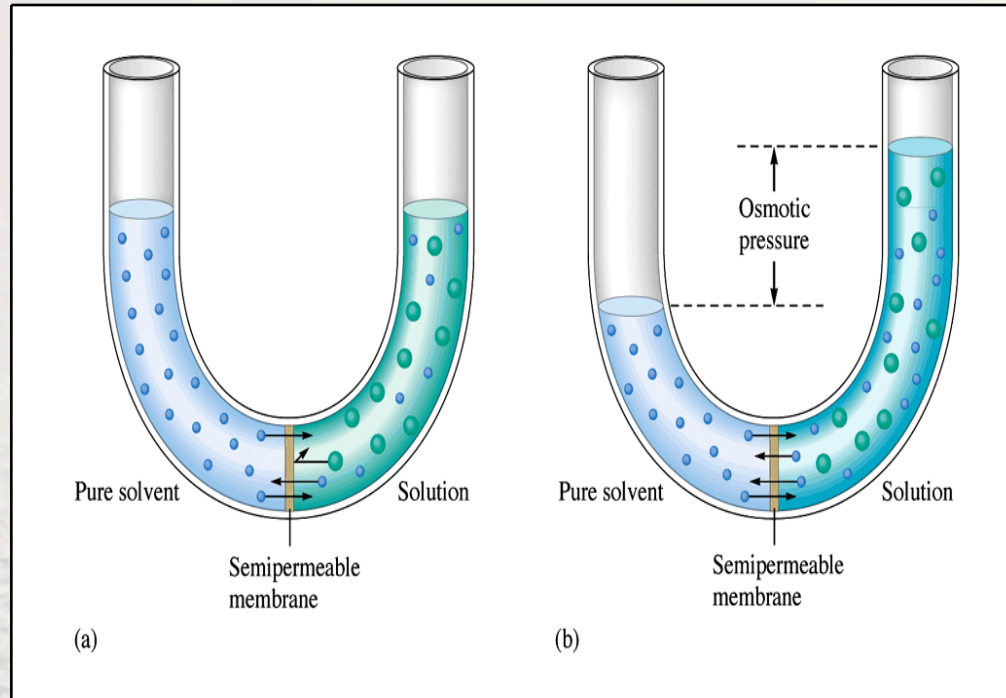
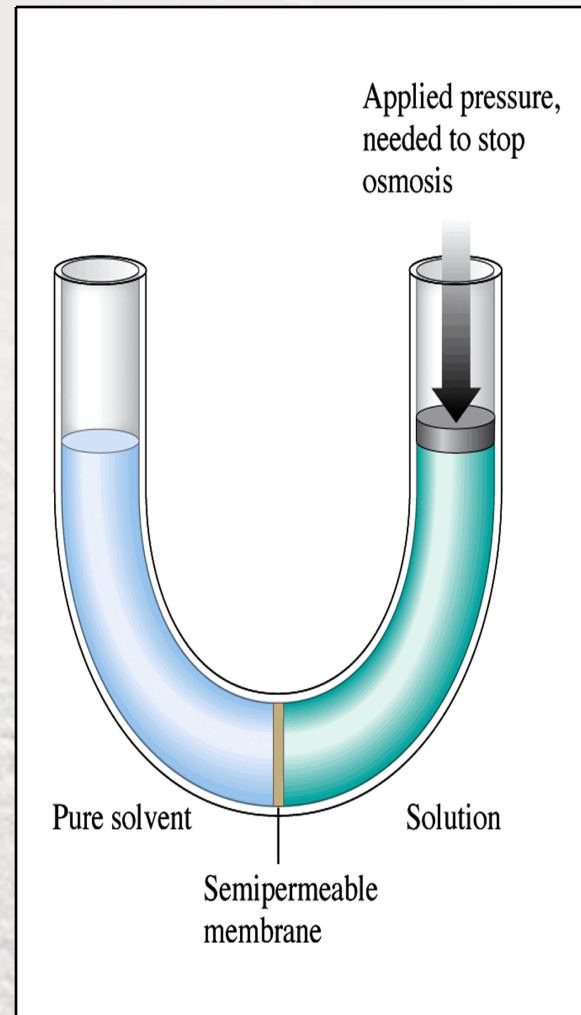


Figure 11.18: (a) A pure solvent and its solution (containing a nonvolatile solute) are separated by a semipermeable membrane through which solvent molecules (blue) can pass but solute molecules (green) cannot. The rate of solvent transfer is greater from solvent to solution than from solution to solvent. (b) The system at equilibrium, where the rate of solvent transfer is the same in both directions.

The normal flow of solvent into the solution (osmosis) can be prevented by applying an external pressure to the solution. The minimum pressure required to stop the osmosis is equal to the osmotic pressure of the solution.



$$\pi = nRT/V = MRTi$$

- π = osmotic pressure
- n = moles of solute
- R = gas constant
- T = absolute temperature
- V = volume of solution
- i = Van't Hoff factor
- M = molar mass

QUESTION



Assuming ideal behavior which of the following statements provides correct comparisons when adding a non-volatile solute to a solvent?

- 1. Vapor pressure decreases; freezing point increases; boiling point increases; osmotic pressure decreases.*
- 2. Vapor pressure decreases; freezing point decreases; boiling point decreases; osmotic pressure decreases.*
- 3. Vapor pressure increases; freezing point decreases, boiling point increases; osmotic pressure increases.*
- 4. Vapor pressure decreases, freezing point decreases, boiling point increases; osmotic pressure increases.*

HW: 66,70,72,76